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Generic Approach to Modeling a Virtual Observatory Integrating Spatio-Temporal and Toponymic Data Dedicated to Health Governance Application to the Gabonese Context

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Abstract

The need for ubiquitous information and knowledge is currently described as an issue by African Governments. To this end, the Gabonese government has decided to set up a program called E-health. Admittedly, experiences and strategies in terms of data infrastructures and open data platforms exist; but the fact remains that their contents are still little known and sometimes unsuitable for exploitation within the framework of the country's development policies. With this article, we are proposing a generic methodological approach that allows the construction of a virtual observatory dedicated to piloting health data. The concept of an observatory is particularly declined through the functionalities it offers. Our approach involves the definition of a global architecture integrating the Gabonese specificities. Such a virtual observatory would facilitate decision-making by public authorities, development partners and researchers, in the context of the implementation of Gabon's development policies and e-government.

Subject Areas

Health Policy

Keywords

Observatory, Spatiotemporal, Toponymic, Gabon, Health, Governance, Geographic Information System

1. Introduction

Since 2009, the Gabonese government has engaged the construction of modern hospitals. Thus, through the Emerging Gabon Strategic Plan (EGSP) [1], important financial resources have been freed up in terms of equipment, drugs and training of health personnel. Despite these efforts, the observation is that the overall management of these health structures remains a thorn in government action. The failure of public policies in this area is almost obvious. We note for example that there is a chronic lack of medicines, insufficient qualified personnel, obsolete equipment, broken down or lacking in consumables, bulky reports transmitted to the Governors but not exploited, etc. One of the reasons for this failure is the absence of a health information system to support a comprehensive development strategy for this sector. This article aims to help fill this void, by proposing the implementation of an e-government component of the health field.

The present work is a synthesis of our study, carried out to propose an approach to modeling and structuring a health information system (HIS) in Gabon. Indeed, one of the current problems in the provision of health care in Gabon remains the access in real time to information and its dissemination. It is within this framework that the present work falls in.

In this article, we first present the context of this work, as well as Gabon's positioning in the field of e-health by relying on the 2018 edition of the United Nations report on e-government [2]. After setting the context of our study, we devote section 3 to the problem and the need for Gabon to have an observatory type solution. Section 4 is devoted to the state of the art. Section 5 deals with the generic model and the model specific to Gabon. In the generic model, we propose a methodological approach aimed at setting up a virtual observatory in any country. In the specific model, on the other hand, we contextualize the generic model to the specificities of Gabon. Section 6 presents the first results of the implementation as well as the architecture of the solution. Finally, we conclude this article with the sketch of perspectives.

2. Background

Since 2010, Gabon has been implementing a new development strategy called "Emerging Gabon Strategic Plan" (EGSP). This plan, structured around three pillars (Green Gabon, Industrial Gabon and Services Gabon), aims at modernizing the country as a whole and in a coherent and coordinated manner. The EGSP insists on the development of sustainable growth and the improvement of social indicators in a context of reduced oil reserves. The immediate challenge for the Gabonese government is to implement this ambitious development plan by means of sectorial strategies with visible results, including, in the short and medium term, poverty reduction.

Through the "Digital Gabon" component, under the "Gabon of Services" pillar, the digital economy has been clearly identified in the EGSP as a key sector

for diversifying the sources of growth in Gabon. Its central and edge-cutting side is well illustrated in the rosette of the Digital Economy (Figure 1). In this context, the health sector has been identified as one of the twelve priority sectors for the use of information and communication technologies (see rosette below right) to improve the efficiency of the health care system.

Nowadays, health information is of paramount importance in the process of improving health care in a country. It is the essential starting point at all levels of decision-making in health systems. This is why the construction of information systems dedicated to this field is essential in any health care system. Indeed, a well-structured health information system promotes the monitoring of progress in population health status indicators, the harmonization of policies and the improvement of performance. To better manage this information flow, one of the most relevant solutions is the establishment of an observatory type management and monitoring mechanism. The latter must be capable of meeting the main requirements of this type of solution, *i.e.*, analysing, sorting and organizing (by theme, public or territory criteria) the content of the database(s) to "produce" intelligible information that can be used as a support for reflection, knowledge and monitoring tools for the population's health status, but also evaluation and decision support tools [3].

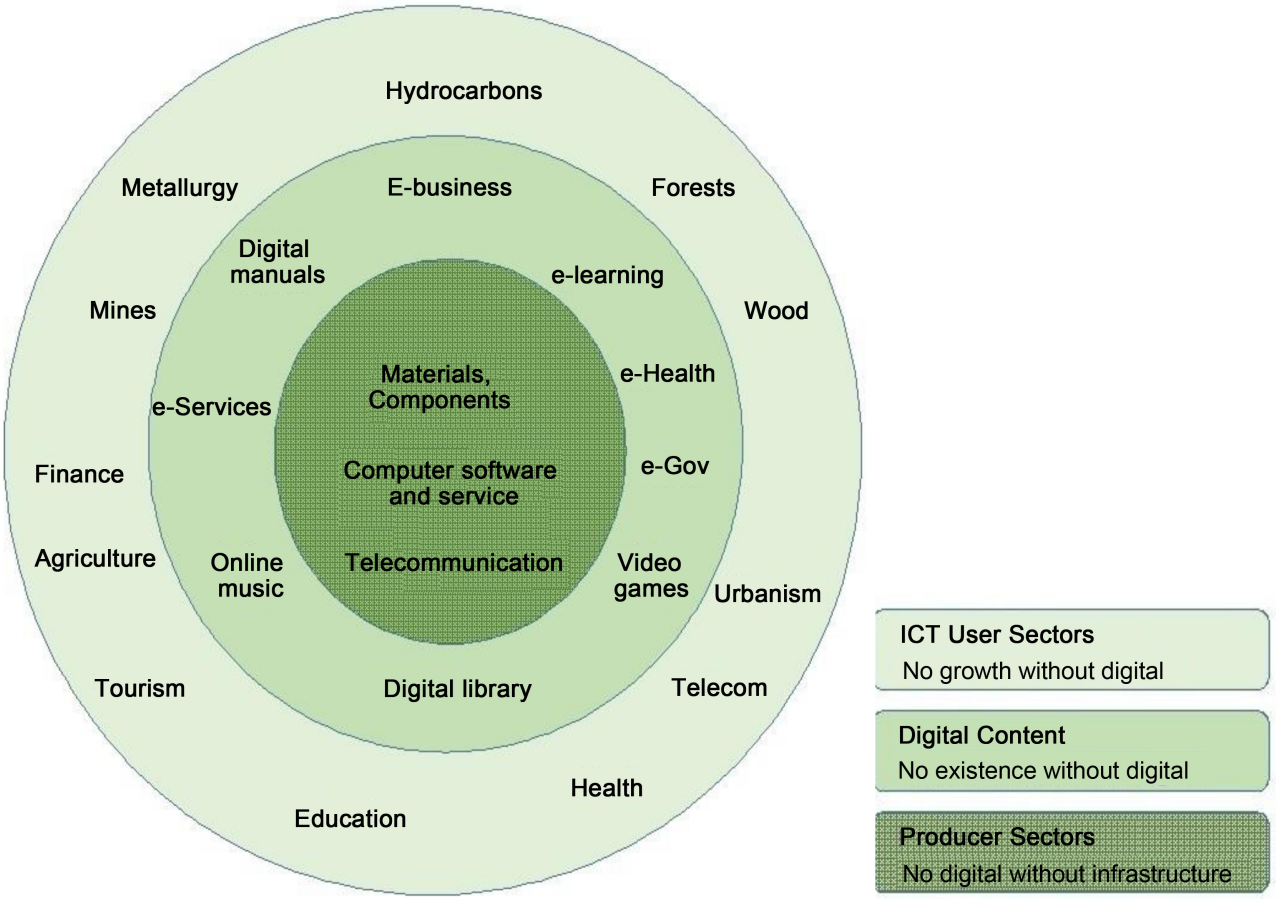

Figure 1. Scope of digital economy [1].

Having understood all the issues related to the organization and structuring of its health system, the Gabonese Government has requested the support of the World Bank to prepare the e-Gabon project, one of the components of which is the NHIS (National Health Infrastructure System) project. The objective is to support the Health Ministry in the design, implementation and development of a genuine national health information system. This development falls within the general framework of the implementation of the Strategic Master Plan of the Health Information System of Gabon (SMPHISG) for the period 2017-2022. In this master plan [4], the objectives are:

- Strengthening the National Health Information System: this action aims to improve the performance of the national health information system by strengthening its human and financial resources, as well as modernizing the equipment and infrastructure of health structures;
- Establishment of an epidemiological surveillance system to anticipate the appearance of epidemics in Gabon, this system will rely on the national health information system to collect the necessary data and disseminate relevant alert and response information.

Moreover, a review of the ranking of the United Nations report on the development of e-government [2] shows that Gabon (cf. **Table 1**) is an intermediate country (EGDI of 0.43; *i.e.* 125th in the world). It ranks above the African average (0.34), and in the same category as countries such as Honduras and Nicaragua in Latin America, Bangladesh in Asia and Rwanda, Algeria and Morocco in Africa. Gabon's position is marked by some contradictions, including a decent human capital (HCI = 0.64), a lagging online services index (OSI = 0.23), a rather high level of income, and a good quality telecommunications infrastructure (ITR = 0.425) with high GSM penetration [5].

The above indicators contrast sharply with reality; this is not surprising, as the successful implementation of e-Government presents major challenges, including the availability and development of adequate infrastructure, the quality of ICT training provision, ensuring privacy and security, user-friendliness and ease of learning and access for vulnerable people. This general and recurrent observation has been made by many researchers in the field of e-administration [6]-[11]. Indeed, this work, generally based on the analysis of data collected by the United Nations (which publishes a report every two years on the global evolution of

Table 1. Gabon's place in e-government [2].

	Index	Value
Rank	Gabon Rank in the World	125
EGDI	E-Government Development Index	0.4313
OSI	Online service Index	0.2292
TII	Telecommunication infrastructure Index	0.4250
HCI	Human Capital Index	0.6398

e-government), and on data from national studies, comes to the following conclusions: at the national level of countries, there are many disparities (divide between administrations, social strata, cities and countryside, contrasts between GDP and digital infrastructures, etc.). According to the same studies, in the Least Developed Countries (LDCs), these cleavages are accentuated by a low level of economic development, almost poor infrastructure, inhibiting ICT progress in the public sector and a low supply of ICT training.

However, all these studies show that the adoption of e-administration by a country requires a significant improvement in the quality and availability of public services to its people. Therefore, it is vital to explore all possible strategies to advance the use of ICT in the public sector in LDCs. The objective is to improve services and outcomes for government and citizens.

Gabon (classified as LDC) is no exception to this observation: the supply of online services is very low and this is its Achilles' heel in the United Nations e-government ranking. Indeed, today this offer is limited to the following services: visas, customs and tax declarations, online student registration on the sites of universities and public colleges, and the preparation of grant applications. However, major government bodies would benefit from offering their services online, to give users better access to associated public services, particularly in the areas of health, social benefits, civil status, education, public procurement, etc.

The setting up of a virtual observatory dedicated to the management of health resources and data, which is the focus of our work, contributes to the development of e-services in the field of health in Gabon and to support its governance.

3. Problem and Need for a Virtual Observatory

In its current functioning, Gabon does not have any observatory, much less a real information system relating to the National Health Infrastructure System; although an implementation plan has been designed through a document called the National Master Plan for the Information System (NMPIS); but it is still purely conceptual. To date, data from the country's health regions and structures are still very scattered. Each entity (health regions or structures) collects its own data, processes and classifies them according to its own interests. These data, which are generally cumbersome and redundant, are described in annual reports. Whether at the regional or health facility level, most information is collected in paper format through registers for administrative purposes. These quasi-manual procedures result in a lack of control over the information.

An analysis of the current situation shows that decision-makers have enormous difficulties in knowing the spatial distribution of health structures and personnel, the health care offers, the needs in terms of medicines and equipment (beds, scanners, etc.), the medical deserts in certain parts of the country, etc. The information is not always available in a timely manner. In addition to the problems we have just raised, it should be pointed out that Gabon has no sectorial information systems in the field of health. This is why the Gabonese authorities

have drawn up a strategy laying in the Strategic Master Plan for the Gabonese Information System. In this plan, Gabon Government proposes an organization based on several levels of information, namely: the hospital information system, the health center information system, the traditional medicine information system, and finally the public health steering information system. Ultimately, all the information must be interoperable with the information system of the National Health Insurance and Social Security Fund (NHISS).

To tackle these problems, the proposal for a virtual observatory seems to be an effective way in centralizing future HIS, organizing existing information and guiding decision-makers with a view to good governance. Several reasons justify this choice. Firstly, observatories have the particularity of responding to societal issues. This is why, in their analysis, [12] stress that, whatever the observatory, it must be able to perform at least diagnostic functions to enable the evaluation of the actions implemented. Next, any observatory should be associated with prognostic functions, to give it the capacity to alert and guide managers in their decision-making in the short and medium term [12]. This is why we opted for a "virtual observatory" type solution.

The work of [13] also supports the central role that an observatory plays in good governance and the beneficial effects that can be derived from it. In their analysis, they show that any society can decide to set up an observatory (or a network of observatories) with the aim of better documenting and understanding the processes behind the issue, to feed/facilitate discussions, even negotiation handling between stakeholders and, in the end, to guide land use planning or resource management decisions according to the Stakes identified. They go on to show that observatories provide observation, monitoring and knowledge enhancement functions. To this end, they recommend three mechanisms in an observatory, namely:

- A sustainable scientific system that creates information to shed light on processes and document the dynamics of the device behind the issue (temporal monitoring). Continuing their argument, [13] emphasize that an observatory enriches knowledge to better answer the question asked.
- A technical device that provides services to acquire, store, process, manage and disseminate the data and information produced.
- An Institutional system that organizes the governance of the observatory, with roles distributed among identified and mobilized actors, and defines the rules for sharing and disseminating data and information.

In order to materialize the role of an observatory in any society, [13] propose a generic model whose UML formalism scheme is presented below (**Figure 2**).

In view of the above, we believe that the observatory type solution is appropriate for our problem, and that it could make up for the shortcomings raised above. In the first stage of its development, the objectives of our observatory will be:

- Facilitate access to information in general;

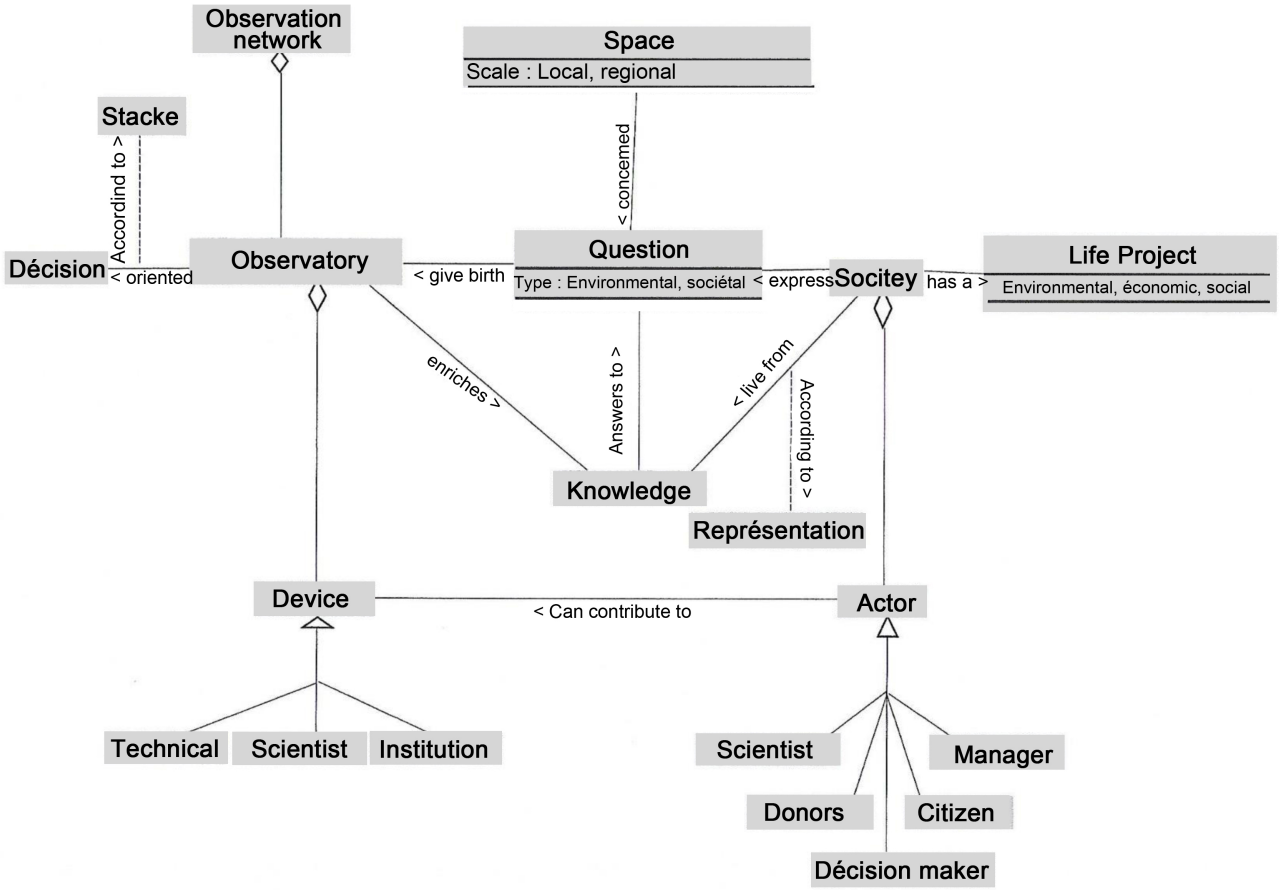

Figure 2. Resumption of the general structure of a scientific observatory proposed by [12] and modified by [13].

- Strengthen the position of the Ministry of Health as the sole regulatory body in the field of organisational analysis and management of health information and health and social structures;
- To make thematic information available to researchers;
- To facilitate the monitoring of the environment of health establishments;
- Establish a health dashboard.

In view of these objectives, the Directory that we are planning to implement is above all a G2G type e-administration tool, as its purpose is to improve the interaction between the various public players working to implement the country's health policy. For the record, e-administration, in a supplier-customer logic, is divided into three forms [2] [9]:

- Government-to-government (G2G), tools for exchange between administrations;
- Government to Citizen (G2C), e-administration tools for users;
- Government to Business (G2B), exchanges between government and business.

In this section, we have raised the problems faced by the Gabonese authorities in the management of health information. We have also shown the importance of having an observatory type decision support tool. We are now summarizing

the state of the art of the scientific work related to the observatories.

4. State of the Art

Faced with the many environmental and societal issues at stake, the concept of an observatory, long devoted to the strict observation of the universe, has evolved profoundly, and various meanings have emerged. Today, this concept is now shared by broad domains, linked to the Digital, ranging from observation and information systems to decision support systems and governance support [12]. Drawing up an exhaustive state of the art on observatories, [12] show that the era of globalization has enabled scientists to progressively implement observatories designed to monitor spatial and temporal changes in phenomena. The work of [14] also confirms this trend. Indeed, through repeated observation, observatories promote understanding of the mechanisms governing phenomena and, if possible, anticipate their evolution. This is why the setting up of observatories is no longer motivated solely by fundamental research questions, as was the case in the past, but now to respond to operational needs, in particular to provide a better response to questions relating to the environment and, above all, to the duality between governance and territory [12].

As highlighted [15], the missions of an observatory remain the same, *i.e.* to observe, monitor, analyze and understand, over a representative portion of space, of a territorial entity, the socio-environmental dynamics resulting from the dynamic interactions of socio-economic and biophysical systems. Observatories therefore play a diagnostic and evaluation role for the actions implemented.

Today, the scientific community is working to design observatory models that, whatever the question posed, support the management of a territory and societies. Several examples exist worldwide. One example is the work of [16], relating to the monitoring by drone photogrammetry carried out since 2006 on the beach of Porsmilin (Brittany, France). They describe a case study showing the potential of drone surveillance to study storm impacts and beach resilience. Addressing the same issues, [17] have led a reflection on the prefiguration of a climate observatory in Lyon-France. For their part, [18] propose an analysis of the impact of agricultural practices on a territory for the recovery of water quality with applications at the level of the Charente basin in South-Eastern France. In their work, they propose the construction of an observatory for the management of surface and ground water quality in support of agro-environmental action programs. Through this observatory, they show the interest of having it available to achieve good chemical and biological water quality, including the preservation of drinking water catchments that combine data on the environments and data on human practices at different scales. As far as they are concerned, [19] have shown the need to set up the urban ecology observatory of Rennes (CNRS INEE Armorial workshop area) on the Prairies Saint-Martin sector. A reflection was carried out from which they developed relevant tools such as POPS, which is a

collaborative management tool for scientific projects, for the administration of information related to project management and valorization, and INDIGEO for the management of scientific data produced in the framework of the observatory.

As regards the health field, we will cite the work of [3] concerning the observatory in Nanterre, France. His work aims to guide public health policy and action on the basis of knowledge of available health indicators at the suburban level. We will also cite the observatory of World Health Organization. In this solution, it is now possible to have a publicly accessible interface for WHO health statistics for the 194 member countries. This observatory includes statistics for more than 1000 indicators, including mortality, child nutrition, maternal health, HIV/AIDS, environmental health, equity, etc. This overview explains the variety of ways in which users can access and browse WHO health statistics.

At the level of Gabon, initiatives on observatories are non-existent. Several bodies such as the National Parks Agency, the Directorate General for the Environment, some Laboratories of the National Center for Scientific Research and Non-Governmental Organisations have thematic data of various kinds. Unfortunately, these data are managed in a scattered manner and are often poorly structured. Whether in the fields of forests, fauna, botany, fisheries, etc., the construction of virtual observatories is non-existent. This is why Gabon is part of this digitization logic through the e-health project integrating our work.

This article proposes a methodology that will enable decision-makers to have a permanent dashboard and an information access system covering all of Gabon's health regions.

5. Virtual Observatory Model Integrating Spatio-Temporal and Toponymic Data Dedicated to Health Governance

Based on the work presented in the state of the art, in particular the general observatory model presented above, in this section we propose an observatory model that best suits our problem; that is, a virtual observatory model integrating spatio-temporal and toponymic data dedicated to health governance. To this end, in this section, we first deal with the generic elements of the model and show the transposability of the model in different African countries with the same health system. Then, we contextualize our model to the specificities of Gabon.

5.1. Generic Model of the Virtual Observatory

Our work concerns an application of the general observatory model presented above (**Figure 2**) to the Gabonese health system. The resulting model (**Figure 3**), presented in the UML formalism, takes into account three essential elements, namely: the dynamic nature of geographical space (time, form and toponym), the description of health structures and the management of their resources.

It should be remembered that the implementation of an observatory requires

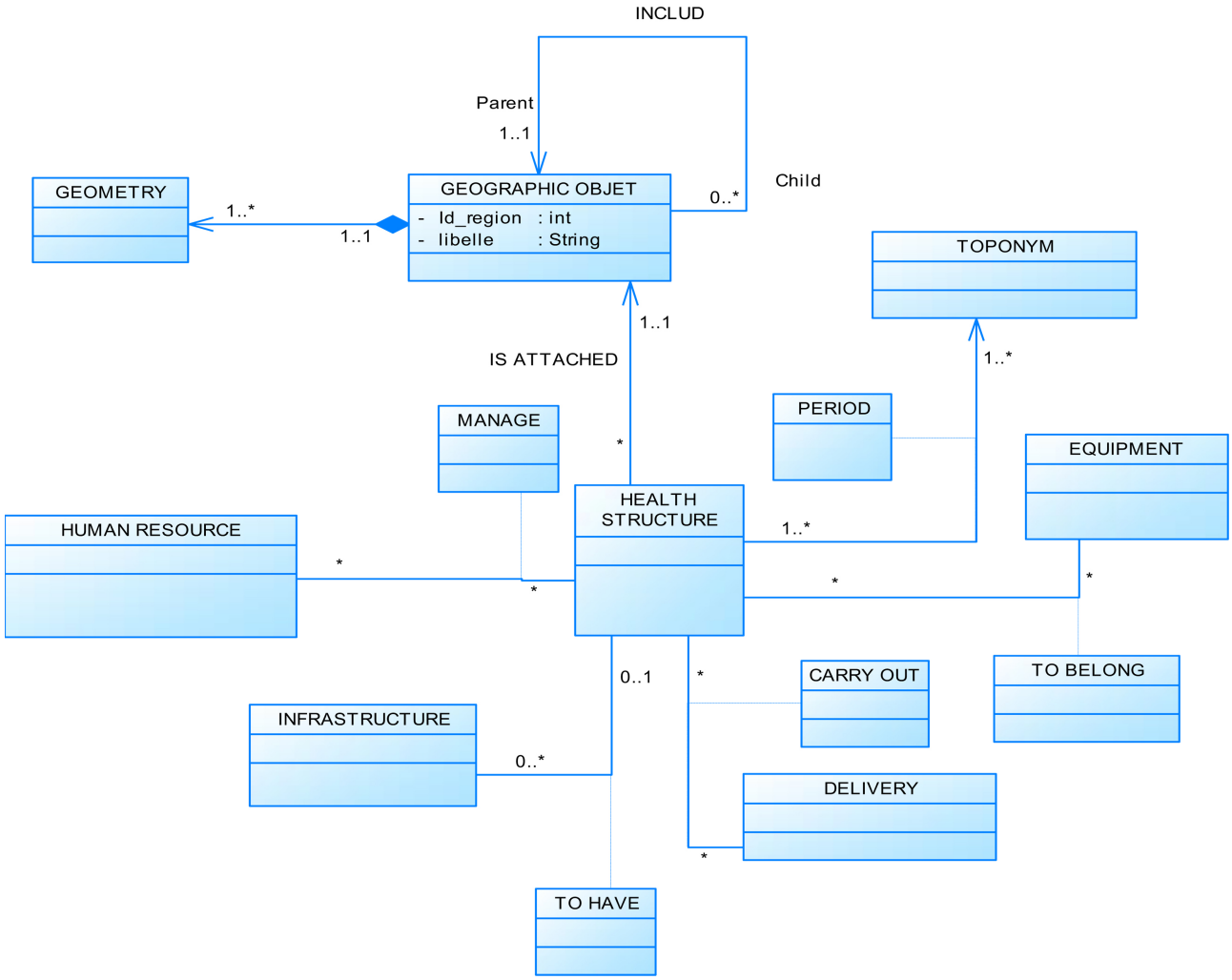

Figure 3. Generic model of a virtual health observatory.

the prior existence of an information system. However, in the case of Gabon, as we pointed out above, the health information system is non-existent. This is why, in our work, we proposed a model to fill this gap: an observatory based on a health information system divided into two components. The first one relates to the geographical distribution of health infrastructures and the second component to their management. The remainder of this sub-section details this organization.

The general architecture of a health system can be found in our model (**Figure 3**) through a hierarchical declination of geographical objects and health structures.

The model proposed above is a generic model through which we situate a country's health facilities according to geographical locations. Every health facility is attached to the abstract class Geographic Object. As noted [20], without geo-spatial data management, the current challenges in Big Data applications such as Earth observation, Geographic Information System integration/building information modelling and 3D/4D urban planning cannot be solved. In addi-

tion, geographic data management plays a connecting role between data acquisition, modelling, visualization and analysis. It enables the continuous availability of spatial data and their replicability. However, geographic objects are constantly evolving. It is therefore important to propose a model that takes into account these changing spatial entities and even their trajectories [20]. In our model, a geographic object can be the parent of another child geographic object which in turn can also be the parent of another child geographic object. Based on the topological operator Tessellation, we can construct a tree cutting out a given territory. The geographical object Father becomes a Tessellation of its Sons. This hierarchical division of geographical objects allows us to categorize the hospitals according to their importance. On a national scale, we find the University Hospital Centres (UHC) and other specialized hospitals. At the regional level there is the Regional Hospital Centres (RHC), while at the departmental level there are the dispensaries and health houses.

In addition to this spatial dimension, the model also integrates the management of toponyms in the identification of health structures. In fact, during field surveys for the inventory of hospital establishments, it emerges that there are health establishments that change their names to other names. During the field surveys, it was also found that some toponymic establishments previously closed due to breaches of the law ended up reopening under other names. In view of this observation, we deemed it useful to integrate the management of toponyms into our model to enable decision-makers to trace them. In this management, we also take into account the names of geographical objects.

In the model, we highlight the various aspects related to the health governance of hospital establishments. An analysis of the latest versions of the health map (year 2017) and the statistical yearbook (year 2017) shows that the following elements are very important in health governance. These are:

- Management of services,
- Management of personnel and specialties,
- Infrastructure,
- Equipment,
- Drugs,
- Medical consumables,
- Services,
- And so on.

The model thus provides for health structures to be able to manage all their data and ultimately produce knowledge that will guide the choices of political decision-makers.

5.2. Specific Model of the Virtual Observatory

Our virtual observatory model is derived from the general model proposed by [12] and modified by [13] (**Figure 2**). It highlights four essential elements, namely: the geographical space to which the observatory applies, the questioning of health governance in Gabon, the knowledge produced from data from health

structures and the decisions that will have to be made as a result. In order to contribute to the structuring of the system on the Gabonese scale, the initial theoretical model above (Figure 3 and Figure 4) is presented as follows:

- Zoning (where): taken into account by dividing the territory into geographical objects. The application of the generic model above, requires specifying the depth of the tree. In this case, this depth is four: Nation, Region, Province and Department. We integrate layers conforming to certain topological requirements. The administrative divisions of successive levels form a complete hierarchical division of space (in the sense of topology) in accordance with the requirements of the Ministry of Health;
- The Geometry of objects: as it evolves in time and space, we have taken the geometry of objects into account in the model. Indeed, we have observed that the administrative organization of Gabon has been very dynamic since 1960. We note for example the creation of new departments or the redrawing of the boundaries of an existing Regions/Departments;
- The health structure (what): once its longitude and latitude was located, we took into account for each health structure the management of Human Resources by category, the management of Infrastructures, the services provided, and finally, all the equipment;

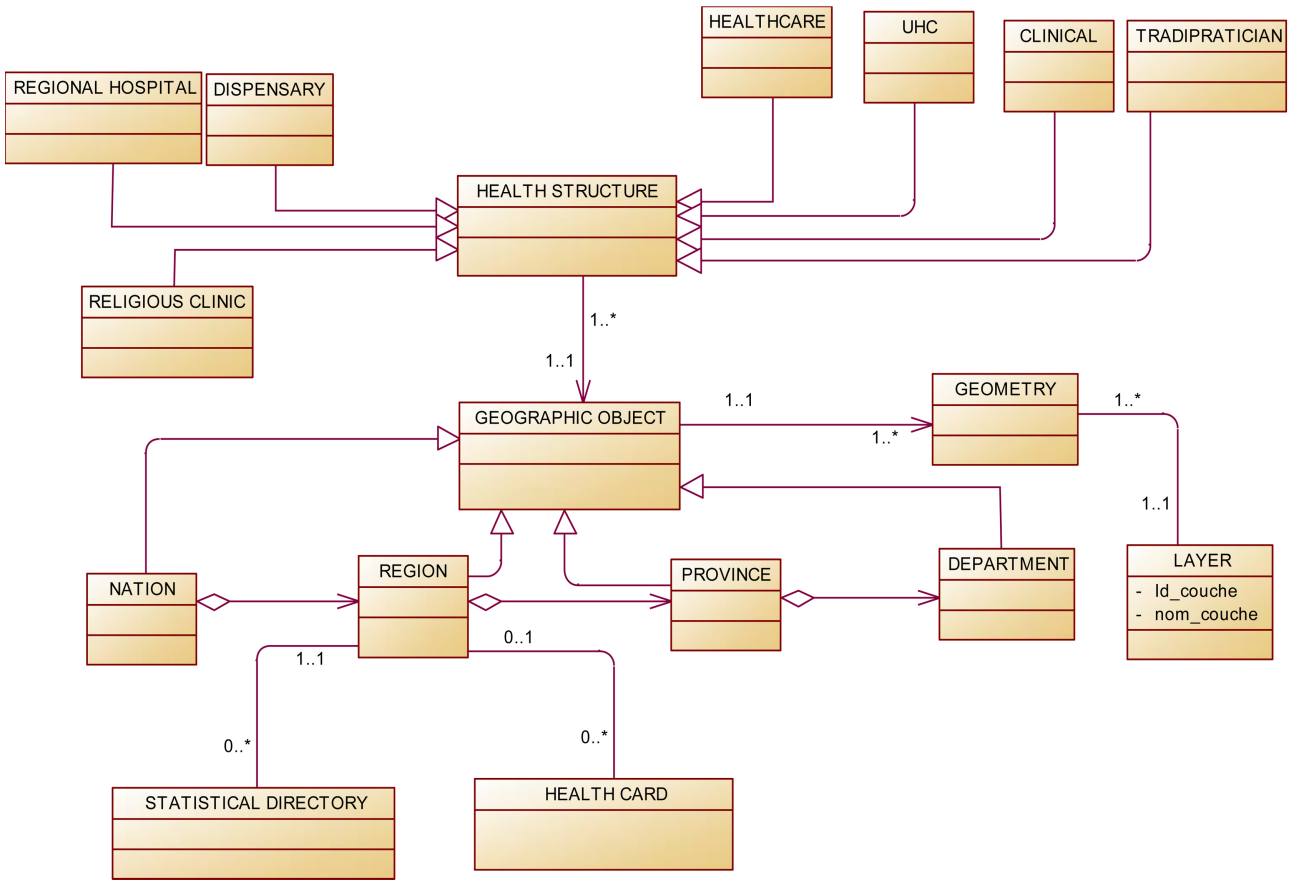

Figure 4. Gabon-specific class diagram of the virtual observatory.

- The production of knowledge: thanks to the data produced in the health structures, the observatory is able to produce for a given period, statistical yearbook, national or regional health map and management chart.

The decision: the three elements above (statistical yearbook, health map and dashboard) must guide the Gabonese government in good governance and improving the provision of health care in the country.

In this model, we have identified four hierarchical levels, namely: the Nation (central infrastructures such as University or specialized hospitals), Region, Province and Department. The Province is the daughter of the Health Region while the Department is the son of the Province. The Health Region is the daughter of the Nation, which is the root. Using the topological operators, the reconstitution of a parent class from its sons is done using the tessellation operator. Thus, the geometry of a Health Region is a tessellation of the Provinces that compose it. In the same way, Province is also a tessellation of the Departments. In the case of Gabon, the depth of the tree is four levels. These division and depth correspond to the requirements of the Gabonese Ministry of Health.

It is important to emphasize that the organization of health structures does not follow any particular hierarchical logic in the private, traditional, religious and community sectors. On the other hand, the public sector is organized as follows:

- At the national (central) level, there are the UHC (University Hospital Centres), which are reference establishments and specialized hospitals;
- In the provincial capitals, there are regional hospital centres (RHC);
- In the departmental capitals, there are dispensaries;
- In villages or groups of villages, there are health houses.

Currently, all these health structures record their health data in voluminous notebooks. These data are then synthesized and transmitted to the management staff at upper level who prepare the annual reports (statistical yearbooks and/or health maps).

6. Implementation of the Observatory

The implementation of the above specific model has enabled a first level of implementation of the virtual observatory. We will quote for example:

- The management of public health structures;
- The management of the names of the places of institutions;
- The map library for the establishment of health map.

It should be noted that a first level of statistical processing is being carried out. There are still several indicators to be defined in this sense, such as the infant mortality rate, HIV AIDS, maternal health, environmental health, etc.

As the UHC and RHC lack information systems capable of processing and analyzing the data in their possession, we have oriented development towards a solution through which the health regions can already produce and disseminate data in their possession.

The screenshot below (**Figure 5**) illustrates how the four elements mentioned

Figure 5. Observatory tool interface: health facility administration form.

above are taken into account in our solution.

The solution has been implemented as a Web application relying on the architectural already available to the Ministry of Health and its branches (health regions). The platform is currently hosted within the Ministry of Health, and health structures can access it via the internet.

7. Conclusion and Outlook

The governance of public health structures in developing countries remains a crucial problem. Despite the huge budgets released every year, the results remain mixed. This is why we believe that another path is needed: the path of e-government. To help decision-makers in this difficult task, it is important for governments to have digital decision-support tools at their disposal. The one we have proposed fits into this perspective. This article proposes a generic approach to the implementation of virtual observatories for the health sector. The model presented above can be adapted to several countries, particularly those in French-speaking Africa with similar health problems. Health and geographic information be the pillars that guide our reflection.

Our solution is currently under development. A first version is already available at the Gabonese Ministry of Health. However, several modules are still to be built. One example is the transition from one dimension (1D) to three dimensions (3D) in the representation of health infrastructures. Such a level of representation will make it possible to have a virtual representation of the buildings and thus to know their state and everything that is in them at any time. Furthermore, drawing on the work carried out in New Zealand by [21], we think that it would be instructive to insert in the observatory a module to assess the main reasons that bring patients into the hospitals. Thus, by combining social, demographic, environmental or other parameters, it would be possible to have

an objective analysis of the reasons for patients' admission to health facilities in urban and rural areas.

Conflicts of Interest

The authors declare no conflicts of interest.

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